**Fabrication of 3D Inter-Wafer Inductor with Magnetic Core**

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**Abstract:**
One method of three dimensional (3D) power delivery architecture was proposed to vertically integrate a cellular array of voltage regulator modules (VRMs) on a thinned wafer with the microprocessor wafer using wafer-to-wafer bonding and through silicon vias (TSVs), with the inter-wafer inductor in between [1]. In this work, an inter-wafer inductor design with magnetic materials will be fabricated using 3D hyper-integration technology. Significant improvement on inductance and L/R ratio is the target of this work, comparing with air core spiral inductor in the frequency range of 1-200 MHz.

**Summary of Research:**
Power delivery is becoming a major issue in deep sub-micron microprocessors due to the rapid increase in power, clock frequency and the continuous decrease in the operation voltage [1]. As future technologies drive supply voltages lower, currents will be driven higher, and parasitics will become more and more problematic. Therefore, new solutions for power delivery are sought.

3D power delivery architecture would provide much shorter interconnects. This means, less parasitic, and significant improvements in the dynamic performance. In particular, it would provide multiple power supplies on the chip, suitable for multi-core processors, ASICs and 3D integrated circuits and systems.

Our group’s 3D power delivery architecture (see Figure 1) will vertically integrate a cellular array of VRMs on a thinned wafer with the microprocessor wafer using wafer-to-wafer bonding and TSVs, with the 3D inter-wafer inductor in between (see Figure 2). The magnetic core of the inductor will be fabricated in the CNF.

Reactive RF sputtering will be used as the method to fabricate the magnetic thin film. The target is made of CoFeAl. The sputtering gas is Ar and O₂. By varying the oxygen percentage in the gas, we could control the oxygen percentage in the thin film. The oxygen percentage is the key to have thin film with good soft-magnetic property and high resistivity.

RF sputtering for magnetic target is quite challenging, especially in the magnetron sputtering system. We managed to get the target sputtered by using very strong magnets (5000G) and thinning the target to 0.05 inch.

The preliminary results give us a good soft-magnetic thin film with a coercive force (Hc) as low as 15 Oe and an anisotropy field (Hk) as low as 100 Oe. The saturation field is as high as 2.3 kG. The resistivity is measured using a 4 point probe and is as high as 403μΩ*cm. Currently the thin film is a good soft-magnetic material. Further experiment will be done to reduce both the Hc and Hk, and increase the resistivity.

**References:**
Figure 1: One schematic of a 3D integration system.

Figure 2: Inductor designs consisting of Cu winding around a CoFeAlO core with (a) oval, (b) octagon, and (c) dodecagon geometries.

Figure 3: B-H graph of thin film Co_{93.8}Fe_{23.4}Al_{13.5}O_{9.3}.